

Simulate Twisted Nematic (TN) Liquid Crystal Cell

Products: FullWAVE FDTD

Applications: Display, Anisotropic Materials

Introduction

Twisted Nematic (TN) Liquid Crystal structures can be used to provide achromatic polarization rotation in thin layers and play important roles in many optical applications such as display panels, modulators, and switches. The optical properties of a twisted TN cell between two polarizers have been theoretically analyzed and experimentally measured ¹. This article studies the well-known example of transmission through a 90-degree TN cell as a function of the cell thickness, as shown in Figure 1.

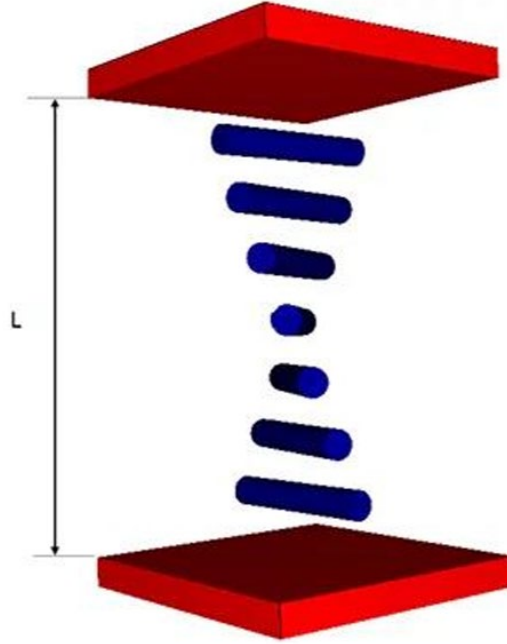


Figure 1. Illustration of Twisted Nematic (TN) cell

Structure and Set-ups Overview

To define this TN Liquid Crystal structure, we will utilize a base anisotropic material, TN having the following refractive index tensor:

$$\mathbf{N} = \begin{bmatrix} N_{xx} & N_{xy} & N_{xz} \\ N_{yx} & N_{yy} & N_{yz} \\ N_{zx} & N_{zy} & N_{zz} \end{bmatrix} = \begin{bmatrix} N_0 & 0 & 0 \\ 0 & N_E & 0 \\ 0 & 0 & N_0 \end{bmatrix} = \begin{bmatrix} 1.543 & 0 & 0 \\ 0 & 1.798 & 0 \\ 0 & 0 & 1.543 \end{bmatrix}$$

Figure 2. Refractive index tensor

¹ Golovin et al, Achromatic Linear Polarization Switch for Visible and Near Infrared Radiation Based on Dual-Frequency Twisted Nematic Cell, Proc. of SPIE Vol. 67 35,67 350E (2006)

We input this anisotropic material in RSoft material editor.

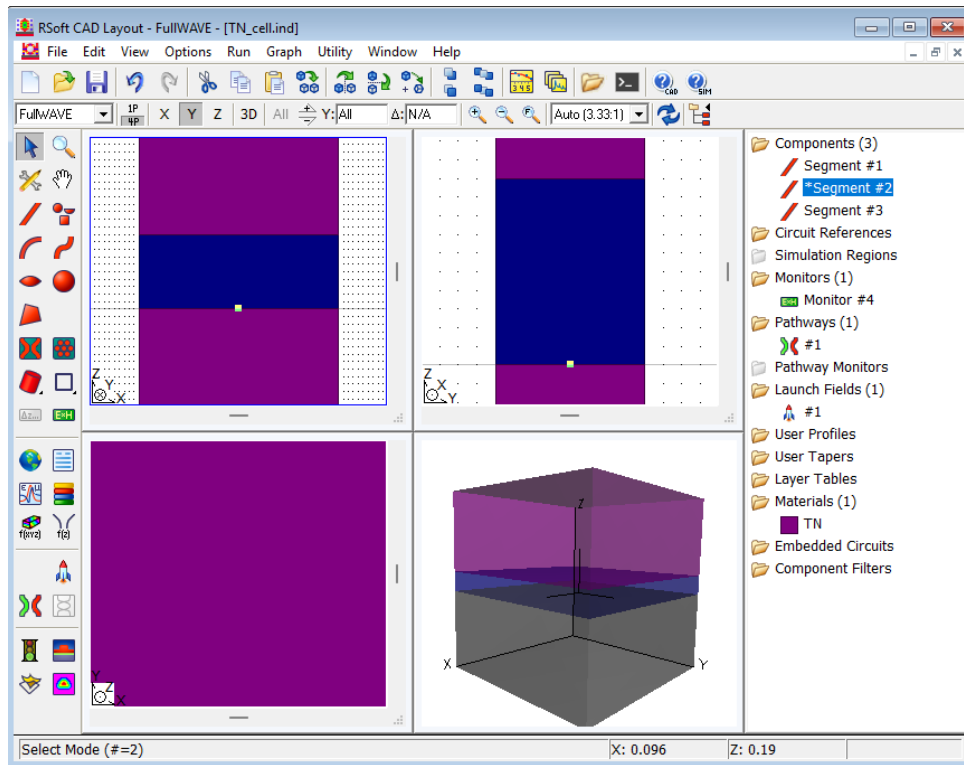


Figure 3. The TN cell, as drawn in the RSoft CAD Environment

Fig.3 is the structure set up in RSoft CAD environment. This structure is composed of three segments, all of which are defined using the same base TN anisotropic material. The crystal axis of this material is rotated around the Z axis to produce the TN structure and is matched between the segments to create a uniform material. The crystal axis of each segment is rotated around the Z axis (Psi) as follows:

- Input Segment (bottom red): This segment is defined via the TN material with a constant Crystal Axis orientation ($\Psi = 0$ degrees).
- TN Segment (dark blue): This segment is defined via the TN material with a linearly tapered Crystal Axis orientation ($0 \rightarrow \Psi \rightarrow 90$). Later, we will study the transmission of the device as a function of the length of this segment.
- Output Segment (top red): This segment is defined via the TN material with a constant Crystal Axis orientation ($\Psi = 90$ degrees).

The excitation field is a TE planewave with a wavelength of $0.6328\mu\text{m}$. Our aim is to measure the transmitted power in the TE field after it passes through the TN segment. We can realize this by using a monitor to measure the Ex-field at the end of the middle-twisted segment. Ex field scan vs LC length L are performed with RSoft's MOST and a metric is used to calculate Transmittance.

Simulation And Results

This example is configured to scan the length of the device (L) to measure the transmission. Please note the following settings in MOST:

- Independent Variables

A scan over the symbol L has been defined. The scan will go from 0.1 μm to 15 μm with an increment of 0.2 μm .

- Measurements

We have activated the *fw_mon_1_ex_last* measurement which corresponds to the steady-state E_x field value saved by the monitor. Note that the value saved by this built-in measurement corresponds to the data plotted via the .ptm file and so it corresponds to E_x^2 .

- Metrics

We have defined one metric to measure the Transmittance of the device for the TE field. Since we are using a plane wave, we can use the formula $(N_e/N_o)/fw_mon_1_ex_last$ which can be derived by dividing the output TE power by the input TE power. Note that the MOST field measurement corresponds to E_x^2 .

The transmittance of the device as a function of its length for incident TE planewave field are shown in Fig.4.

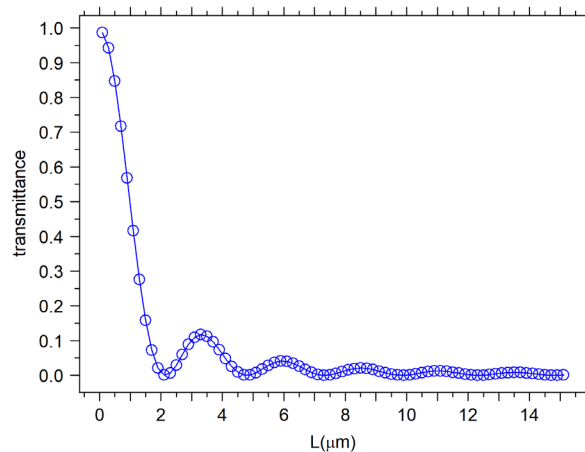


Figure 4. Calculated Transmittance vs. TN cell length

To obtain the typical plot of the Transmittance vs. the Mauguin condition $U = \pi L \Delta n / (\lambda \theta)$, we need to scale the X axis of the plot shown in Fig 4. (θ is the total twisted angle, it is $\pi/2$ here). For this example, we can scale the X axis by $\pi \Delta n / (\lambda \pi/2) = 0.805941858$ to obtain the plot shown in Fig. 5.

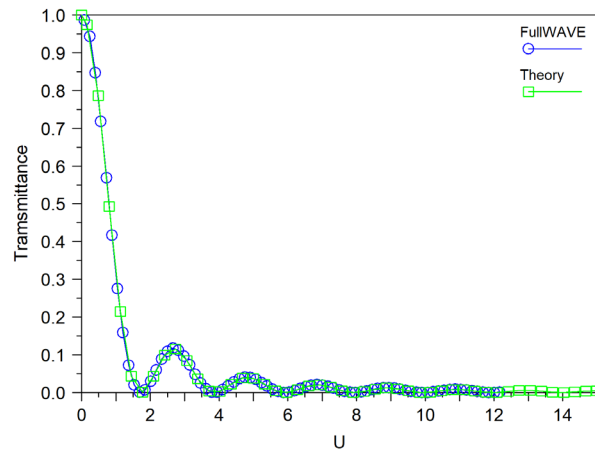


Figure 5. Plot of simulated Transmittance vs. Mauguin parameter u (blue). Also shown is the predicted Transmittance (green) calculated using Equation 1 in Ref 1.

Example Files

Supporting Files for RSoft Application Note "Simulate Twisted Nematic (TN) Liquid Crystal Cell"

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